

AN IMPROVED ASSISTED POWER-UP AND HAND-OFF SYSTEM AND METHOD

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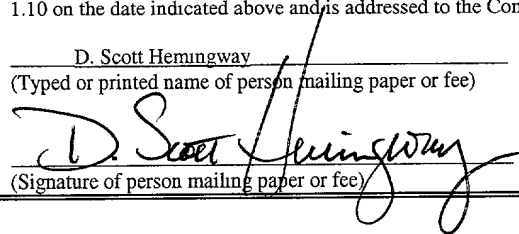
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Related Application Data

This application is the utility patent application related to provisional application Serial No. 60/238,899 filed October 10, 2000.

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Technical Field of the Invention

A power-up and hand-off communication protocol in a packet-based communication system.

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5 BACKGROUND OF THE INVENTION

Present-day Internet communications represent the synthesis of technical developments begun in the 1960s. During that time period, the Defense Department developed a communication system to support communications
10 between different United States military computer networks, and later a similar system was used to support communications between research computer networks at United States universities.

The Internet

The Internet, like so many other high tech developments, grew from
15 research originally performed by the United States Department of Defense. In the 1960s, Defense Department officials wanted to connect different types of military computer networks. These different computer networks could not communicate with each other because they used different types of operating systems or networking protocols.

20 While the Defense Department officials wanted a system that would permit communication between these different computer networks, they realized that a centralized interface system would be vulnerable to missile attack and sabotage. To avoid this vulnerability, the Defense Department required that the interface system be decentralized with no vulnerable failure points.

25 The Defense Department developed an interface protocol for communication between these different network computers. A few years later,

5 the National Science Foundation (NSF) wanted to connect different types of computer networks located at research institutions across the country. The NSF adopted the Defense Department's interface protocol for communication between the research computer networks. Ultimately, this combination of research computer networks would form the foundation of today's Internet.

10 Internet Protocols

The Defense Department's interface protocol was called the Internet Protocol (IP) standard. The IP standard now supports communication between computers and networks on the Internet. The IP standard identifies the types of services to be provided to users and specifies the mechanisms needed to support these services. The IP standard also describes the upper and lower system interfaces, defines the services to be provided on these interfaces, and outlines the execution environment for services needed in this system.

A transmission protocol, called the Transmission Control Protocol (TCP), was developed to provide connection-oriented, end-to-end data transmission between packet-switched computer networks. The combination of TCP with IP (TCP/IP) forms a system or suite of protocols for data transfer and communication between computers on the Internet. The TCP/IP standard has become mandatory for use in most packet switching networks that connect or have the potential for utilizing connectivity across networks or sub-network boundaries.

5 A computer operating on a network is assigned a unique physical address under the TCP/IP protocols. This is called an IP address. The IP address can include: (1) a network ID and number identifying a network, (2) a sub-network IP number identifying a substructure on the network, and (3) a host IP number identifying a particular computer on the sub-network. A header data field in the
10 information packet will include source and destination addresses. The IP addressing scheme imposes a sensible addressing scheme that reflects the internal organization of the network or sub-network.

 A router is located on a network and is used to regulate the transmission of information packets into and out of computer networks and sub-networks. A
15 router interprets the logical address of an information packet and directs the information packet to its intended destination. Information packets addressed between computers on the sub-network do not pass through the router to the greater network, and as such, these sub-network information packets will not clutter the transmission lines of the greater network. If data is addressed to a
20 computer outside the sub-network, the router forwards the data onto the greater network.

 The TCP/IP network includes protocols that define how routers will determine the transmission path for packets through the network. Routing decisions are based upon information in the IP header and entries in a routing
25 table maintained on the router. A routing table possesses information for a router

5 to make a determination on whether to accept the communicated information packet on behalf of a destination computer or pass the information packet onto another router.

The routing table can be configured manually with routing table entries or with a dynamic routing protocol. In a dynamic routing protocol, routers update
10 routing information with periodic information packet transmissions to other routers on the network. The dynamic routing protocol accommodates changing network topologies, network architecture, network structure, layout of routers, and interconnection between hosts and routers.

The IP-Based Mobility System

15 The Internet protocols were originally developed with an assumption that Internet users would be connected to a single, fixed network. With the advent of portable computers and cellular wireless communication systems, the movement of Internet users within a network and across network boundaries has become common. Because of this highly mobile Internet usage, the implicit design
20 assumption of the Internet protocols has been violated.

In an IP-based mobile communication system, the mobile communication device (e.g. cellular phone, pager, computer, etc.) can be called a mobile node. Typically, a mobile node maintains connectivity to its home network through a foreign network. The mobile node will always be associated with its home
25 networks for IP addressing purposes and will have information routed to it by

5 routers located on the home and foreign networks. The routers can be referred to by a number of names including Home Agent, Home Mobility Manager, Home Location Register, Foreign Agent, Serving Mobility Manager, Visited Location Register, and Visiting Serving Entity.

Authenticate, Authorize, and Accounting

10 In an IP-based mobile system, the mobile node maintains its connectivity to the home system through a foreign network. While coupled to a foreign network, the mobile node will be assigned a temporary IP address, so information packets addressed to the mobile node can be routed to the temporary IP address for the mobile node on the foreign network.

15 When a mobile node is operating on a foreign network, specialized servers are used to authenticate, authorize, and collect accounting information for services rendered to the mobile node. This authentication, authorization, and accounting activity is called "AAA," and AAA computer servers on the home and foreign network perform the AAA activities.

20 Authentication is the process of proving one's claimed identity, and security systems on a mobile IP network will often require authentication of the system user's identity before authorizing a requested activity. The AAA server authenticates the identity of an authorized user and authorizes the mobile node's requested activity. Additionally, the AAA server performs the accounting
25 functions by tracking usage on the network.

5 Functionally, a mobility manager will communicate with the AAA server
in the current domain, allocating another router to route information packets
destined for a mobile node while it is located away from its home sub-network.
The mobility manager may have access to authentication and key generation
AAA functions to authenticate and generate session keys. The mobility manager
10 may also perform agent functions to forward packets to the mobile node until
registration is completed.

IP Mobility Protocol

During the formative years since the Internet was first established, Internet
Protocol version 4 (IPv4) was recognized and adopted as the standard Internet
15 protocol. With the advent of mobile IP and proliferation of computers and
computer systems linked to the Internet, various limitations in the IPv4 standard
and associated procedures have developed and emerged. The most pressing
limitation in IPv4 is the restriction on number of IP addresses. As shown in Fig.
1B, the address field size in an IPv4 packet is only 32 bits.

20 A number of benefits emerge from having a larger address field. First,
there is little chance of exhausting the number of possible IP addresses. Second, a
large address field allows aggregation of many network-prefix routers into a
single network-prefix router. Finally, large addresses allow nodes to auto
configure using simple mechanisms. More efficient system designs are thus

5 possible with an expanded address space. Thus, there is a need for an IP standard with a larger IP address space.

In wireless IP networks and sub-networks (divisions of a network), mobile nodes can be physically located anywhere on the network or sub-network.

Wireless IP networks handle the mobile nature of mobile nodes with power-up
10 and hand-off procedures designed to inform the mobile node's home network and sub-network of the location of the mobile node for packet routing purposes.

Because mobile nodes can move within sub-networks and between networks, hand-off procedures need to be implemented to insure that packets are continually routed to the mobile node as it moves from one network to another or from one
15 sub-network to another.

Current protocols for obtaining a care-of address and procedures for power-up registration and hand-off procedures are insufficient to handle current packet-based communication demands. For example, the prior power-up and hand-off protocols utilize system architecture that was designed to operate within
20 the constraints of IPv4's limited address space. These constraints are insufficient for supporting a standard that needs a larger address space and the associated network design architecture. Therefore, a need exists to establish a new user protocol for power-up and hand-off procedures for mobile IP networks using an expanded address space.

5 A new protocol for power-up and hand-off is also needed to satisfy the following criteria:

- 1) Data transfer to a given mobile node should not be hampered by the introduction of additional functional architecture,
- 2) The new protocol should require only *minimal extensions* and
10 should exploit and track evolving routing and addressing capabilities,
- 3) The new protocol should be generic and independent of the type of wireless technology or access medium,
- 4) The protocol should fully support and be consistent with an AAA architecture,
- 15 5) The new protocol should optimize air interface usage for efficiency, reducing the number of required overhand messages, such as Binding Update and Binding Acknowledgement messages, and
- 6) The protocol should also offer protection against over-use or monopolization of resources by certain mobile nodes.

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SUMMARY OF THE INVENTION

The present invention offers new methodologies or protocols for establishing a communication link with a mobile node at power-up and maintaining that link with hand-off procedures on or between networks. The
25 invention uses care-of addressing located in an expanded address field in request

5 and response messages. The invention also, at times, uses Dynamic Host Configuration Protocol (DHCP) servers and AAA computer servers to facilitate power-up registration and hand-off procedures involving a mobile node. Using the DHCP server streamlines the procedure, reducing packet transmission overhead and improving the efficiency of the system.

10 The first embodiment of the invention is called Intra-Domain Power-Up Registration. This embodiment specifies registration message flow when a mobile node powers-up in a foreign sub-network located on a home domain, sending registration message through a serving mobility manager (SMM) to a DHCP server.

15 The second embodiment is for Reactive Intra-Domain Hand-off, and this embodiment is used when the mobile node is performing hand-off from a sub-network to another sub-network within the home network. In this embodiment, the mobile node has no forewarning of the move from one sub-network to another.

20 The third embodiment is a Proactive Intra-Domain Hand-off. This embodiment is used where the mobile node has knowledge that it will move to a new sub-network, but the mobile node does not yet have a link layer connectivity established with the new sub-network.

The fourth embodiment of the invention is the Inter-Domain Power-Up
25 Registration protocol, which is used when the mobile node powers up on a foreign

5 domain. In this embodiment, the mobile node registers through the AAA server on the foreign network.

The fifth embodiment of the invention is the Reactive Inter-Domain Hand-off protocol, which is used when the mobile node moves into a new foreign domain. The mobile node in this embodiment must use the AAA server to
10 register on the foreign network.

The sixth embodiment of the invention is the Proactive Inter-Domain Hand-off and covers the situation where the mobile node is aware that it will move to a new sub-network that is part of a foreign network, but the mobile node does not have a link connectivity established with the new foreign sub-network.
15 The present invention uses an expanded address format over IPv4, and is intended to reduce the amount of registration control, management messages (e.g. Request and Response messages), and information messages (e.g. Binding Update and Binding Acknowledgement). This invention will increase efficiency of transmission and speed up the mobile IP systems because it reduces the amount of
20 overhead message transmission and routing.

BRIEF DESCRIPTION OF THE DRAWINGS

The objects and features of the invention will become more readily understood from the following detailed description and appended claims when

5 read in conjunction with the accompanying drawings in which like numerals represent elements and in which:

Fig. 1 is a communication network for the Intra-Domain Power-Up Registration embodiment where a mobile node powers-up on a foreign sub-network of its home network;

10 Fig. 1A is the information packet format used in the present invention;

Fig. 1B is the prior art information packet format;

Fig. 2 is a message flow diagram for registration of the mobile node in the embodiment of Fig. 1 for an Intra-Domain Power-Up Registration;

15 Fig. 3 is a communication network for the Reactive Intra-Domain Hand-off with a mobile node moving from a sub-network, with no advance notice, to a foreign sub-network;

Fig. 4 is a message flow diagram for the Reactive Intra-Domain Hand-off for a mobile node performing a hand-off in Fig. 2;

20 Fig 5. is a communication network with a mobile node performing a Proactive Intra-Domain Hand-off moving, with advance notice, from a sub-network to a foreign sub-network on a home network;

Fig. 6 is a message flow diagram for a mobile performing a Reactive Intra-Domain Hand-off in Fig. 5;

5 Fig. 7 shows a home communication and a foreign communication network with a mobile node powering up on the foreign network in an Inter-Domain Power-Up Registration;

Fig. 8 is a message flow diagram for an Inter-Domain Power-Up Registration of the mobile node on the foreign network in Fig. 7;

10 Fig. 9 shows a home communication network and two foreign communication networks, with a mobile node moving unexpectedly from one foreign network to another and performing a Reactive Inter-Domain Hand-off;

Fig. 10 is a message flow diagram for the Reactive Intra-Domain Hand-off of the mobile node in Fig. 9;

15 Fig. 11 shows a home communication network and two foreign communication networks, with a mobile node moving with advance notice from one foreign network to the other and performing a Proactive Inter-Domain Hand-off; and

20 Fig. 12 is a message flow diagram for the Proactive Inter-Domain Hand-off of the mobile node in Fig. 11.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 shows a Mobile Node (MN) 64 powering up on a foreign sub-network 50 of a home network 100. The home network 100 has a central buss
25 line 54 coupled to a home AAA server (HAAA) 20 by communication link 55, a

5 DHCPv6 server 30 coupled by communication link 56 to the buss line 54, a home mobility manager (HMM) 40 coupled by communication link 17 to the buss line 54, and a serving mobility manager (SMM) 10 coupled by communication link 15 to the buss line 54. The home sub-network 51 of the MN 64 consists of the HMM 40 coupled to the home agent 25 by communication link 19. The foreign sub-
10 network 50 consists of the SMM 10. MN 64 is linked to SMM 10 by a communication link 62, which may be a wired or wireless connection.

In Figure 1, the MN 64 is powering up on a foreign sub-network 50. Figure 2 shows the registration message flow for the situation where the MN 64 powers up on a foreign sub-network within the home network. This embodiment
15 is referred to as an Intra-Domain Power-Up Registration. The MN 64 constructs a local IP address for use on the foreign sub-network 50 by sending a Registration Request message (Reg Req) 105 to the SMM 10. This Reg Req 105 is for allocation of a co-located, globally routable long-term IP address for the MN 64 while it remains on the current sub-network 50. The Reg Req 105 also contains
20 coincidental information to verify the identity of the MN 64. The SMM 10 will validate the identity of the MN 64, and then send a DHCPv6 Request message (DHCPv6 Req) 110 to the DHCPv6 server 30 requesting a new address for MN 64. The DHCPv6 server 30 allocates a new address to use as a care-of address and sends a DHCPv6 Reply message (DHCPv6 Rep) 115 back to the SMM 10
25 with the new address. The SMM 10 relays this new address to the MN 64 with a

5 Registration Response message (Reg Res) 120. The format of the IP header in the
Registration Response message Reg Res 120 is shown in Figure 1A.

Figure 1A shows the new information packet's IP header format with an
expanded address field. The Version (V) field 71 is a 4-bit long data field that is
used to designate the IP version number. The Priority (P) field 72 designates the
10 desired delivery priority of the information packet. The Payload Length field
(PL) 74 is the length of the rest of the packet following the IP header fields in
octets. The Next Header field (NH) 76 identifies the type of header immediately
following the IP header fields. The Hop Limit field (HL) 75 is an 8-bit integer
value that is decremented by 1 for each node that forwards the packet. The
15 Source Address field (SA) 77 is the 128-bit address of the source node of the
information packet. The Destination Address field (DA) 78 is the 128-bit address
of the intended destination node. Various message extension types, additional
headers, and data fields can be found in the Payload fields (PLD) 79, the Reg Res
120 and Reg Req 105 being two of the possible types. The 128-bit care-of
20 address will be in one of these PLD fields 79 in Reg Res 120.

Figure 1B shows the prior art IPv4 information packet's IP header format.
The Version (V) field 81 is a 4-bit long field that is used to designate the IP
version number (version 4 in this case). The Internet Header Length field (IHL)
82 is 4-bits long and is the length of the IP header in 32-bit words. The Type of
25 Service (TOS) field 83 is 8-bits long and is an abstract indication of the quality of

5 service desired. The Total Length (TL) field 84 is 16-bits long and is the length of the information packet in octets.

The Identification field (ID) 85 is 16-bits long and is assigned by the source node to aid in assembling fragments of an information packet at the destination node. The Flag field (F) 86 is a 3-bit field with control bit flags. The
10 Fragment Offset field (FO) 87 is a 13-bit long field that indicates where the information packet belongs in a multiple-packet message. The Time-to-Live (TTL) field 88 is an 8-bit long field that indicates the maximum time the information packet will be allowed to exist in the system before deletion. The time unit indicated is seconds. The Protocol field (P) 89 will indicate the next
15 protocol level used in the Payload portion (PLD) 95 used in the information packet. The header Checksum field (CS) 90 is used to verify the information packet.

The Source Address field (SA) 91 is a 32-bit field identifying the source of the information packet. The Destination Address field (DA) 92 is a 32-bit field
20 identifying the intended destination of the information packet. The Payload fields (PLD) 93 are found after the IP header and include various message extensions, additional headers, and data fields. Compared to the IPv4 address fields, which include possible care-of addresses, the new message format shown in Figure 1A offers address fields four times larger than found in IPv4.

5 The new address allocated by Reg Res 120 is used by the MN 64 as the
care-of address for routing data packet while it remains on the foreign sub-
network 50. After receiving the allocated new address, the MN 64 sends a
Binding Update (BU) message 125 to the HMM 40 on the home sub-network 51.
The HMM 40 may allocate a router, HA 25, to provide routing and other services
10 to the MN 64. If the HMM 40 allocates HA 25, a Binding Update (BU) message
130 is transmitted to HA 25. The allocated HA 25 registers the MN 64 and
responds with a Binding Acknowledgement (BA) message 135 to the HMM 40.
The HMM 40 will transmit a Binding Acknowledgement (BA) message 140 back
to MN 64 confirming receipt of the BU 125 and binding.

15 Figure 3 depicts the situation where a mobile node moves unexpectedly
from one sub-network 281 to another sub-network 280 within a home network
300 and must perform a hand-off routine. The embodiment to handle this
situation is referred to as a Reactive Intra-Domain Hand-off. Figure 3 shows a
MN 264 linked to a transceiver 260 by a communication link 266. The
20 transceiver 260 is linked to a sub-network 280 on network 300 via new SMM
(nSMM) 210 by communication link 259. Although this link to the network 300
is a wireless connection, alternatively the connection could be a wired connection
linking the MN 264 to the nSMM 210. The sub-network 280 consists of nSMM
210, and it is a foreign sub-network 280 for the MN 64 on the home network 300.
25 The nSMM 210 is linked to a central buss line 254 by communication link 215.

5 A home AAA server (HAAA) 220 is coupled to the buss line 254 by
communication link 255, and a DHCPv6 server 230 is coupled to buss line 254 by
communication link 256. The old SMM (oSMM) 212 is coupled to the buss line
254 by communication link 216. A home agent (HAn) 226 is connected to
oSMM 212 by communication link 263. The oSMM 212 and HAn 226 form
10 another foreign sub-network 281 on the home network 300.

A HMM 240 is coupled to the buss line 254 by communication link 217,
and a home agent (HAm) 225 is coupled to HMM 240 by communication link
219. The HMM 240 and HAn 225 are the MN 64's home sub-network 282 on the
home network 300. The network 300 is linked to the Internet 235 by
15 communication link 271 connected to central buss line 254. A correspondence
node (CN) 274 is also linked to the Internet 235 by communication link 272,
which may be a wired or wireless link. MN 264' is the prior location of MN 264,
which is shifting connection on network 300 as shown.

In Figure 3, the MN 264' is shown connected to the foreign sub-network
20 281 and is moving unexpectedly from an area covered by oSMM 212 on foreign
sub-network 280 to an area covered by nSMM 210 on foreign sub-network 281.
Figure 4 shows the message flow for this embodiment where MN 264 is
performing hand-off from one foreign sub-network 281 to another foreign sub-
network 280 within a home network 300 without prior notice. This new
25 embodiment is referred to as a Reactive Intra-Domain Hand-off.

5 In Figure 4, the MN 264 constructs a local IP address for use on the
foreign sub-network by sending a Reg Req message 305 to the nSMM 210. The
Reg Req 305 is for allocation of a globally routable IP address for MN 264 to use
on the current sub-network 280. The format of the IP header for Reg Req 305 is
the same as shown in Fig. 1A. The MN 264 will also provide coincidental
10 information to verify its identity in the Reg Req 305. The nSMM 210 verifies the
identity of the MN 264 and then transmits a DHCPv6 Req 310 to the DHCPv6
server 230 requesting allocation of an IP address. The DHCPv6 server 230
allocates a care-of address and transmits a DHCPv6 Res 315 back to the nSMM
210 with the care-of address. The nSMM 210 then transmits a Reg Res message
15 320 containing the allocated new address.

After forwarding the Reg Res 320 to the MN 264, the nSMM 210
transmits a System Hand-off and Context Request message (SHC Req) 325 to the
oSMM 212. Upon receiving the SHC Req 325, the oSMM 212 will task HAn 226
to forward information packets from the previous care-of address to the new care-
20 of address (e.g. the new address allocated by DHCPv6 server 230). To task HAn
226, the oSMM 210 sends a Binding Update message (BU) 330 to HAn 226 along
the same link the previous care-of address is located on. The HAn 226 responds
with a Binding Acknowledgement message (BA) 335. The oSMM 212 then
sends a System Hand-off and Context Reply (SHC Rep) 340 back to nSMM 210

5 providing user context data, which is composed of information such as session keys for the type of services granted.

After being assigned a care-of address in the Reg Res 320 and receiving context data, the MN 264 sends a BU 345 to the HMM 240, which includes a list of all IP addresses of all correspondent nodes the MN 264 is communicating with
10 (e.g. CN 274). When the HMM 240 receives the BU 345, it allocates a home agent - HAm 225 - to serve the MN 264, and sends a BU 350 to bind the designated HAm 225. The HAm 225 processes and validates the BU 350. After completing processing of the BU 350, the HAm 225 sends a BA 355 to the HMM 240.

15 Upon receipt of the BA 355, the HMM 240 sends a BA 360 to the MN 264, and the HMM 240 updates all the correspondence nodes listed by the MN 264 in the BU 345 (e.g. CN 274) with the care-of address. This is accomplished by sending a BU 365 to CN 274 (and any other node), which will reply with a BA 370. After a specified period of time to allow forwarding of all messages, the
20 allocation of HAn 226 expires, because all future messages are forwarded to the care-of address and/or the HAm 225.

Figure 5 depicts a MN 464 linked to a foreign sub-network 481 on its home network 500. The MN 464 is aware it will move to a new foreign sub-network 480, which consist of an nSMM 410, but the MN 464 does not yet have a
25 link layer connectivity established with the new sub-network 480. The home

5 network 500 consists of a HAAA server 420, a DHCPv6 server 430, nSMM 410,
a HMM 440, a HAm 425, an oSMM 412, and a HAn 426.

The MN 464 is connected to a transceiver 460 by wireless link 466. The
transceiver 460 is connected to the oSMM 412 by communication link 459.

Although this communication link from the MN 464 to the oSMM 416 includes a
10 wireless connection, this link could alternatively be a wired connection linking
MN 264 to oSMM 412. The oSMM 412 is coupled to a HAn 426 by
communication link 463 and to bus line 454 by communication link 416. Foreign
sub-network 481 consists of oSMM 412 and HAn 426.

The DHCPv6 server 430 is connected to buss line 454 by communication
15 link 456. The HAAA 420 is connected to buss line 454 by communication link
455. The HMM 440 is connected to buss line 454 by communication link 417.
HMM 440 is also connected to HAm 425 by communication link 419. Home
sub-network 482 consists of nHMM 440 and HAm 425. The nSMM 410 is
connected to the buss line 454 by communication link 415, and foreign sub-
20 network 480 consists of nSMM 410. The home network 500 is connected to the
Internet 435 by communication link 471 to buss line 454. Correspondence node
(CN) 474 is connected to the Internet 435 by communication link 472, which may
or may not include a wireless link. The MN 464' connected to nSMM 410 is the
future location of MN 464.

5 Figure 6 shows the message flow for the embodiment in Figure 5, referred
to as a Proactive Intra-Domain Hand-off. When the MN 464 detects that it will
move to new sub-network 480 on the home network 500, it sends a System Hand-
off Request message (SHO Req) 505 to the oSMM 412, the current serving
mobility manager on sub-network 481. The format of IP header for SHO Req 505
10 is the same as shown in Fig. 1A. The oSMM 412 transmits a Hand-off and
Context Transfer Request message (HCT Req) 510 to the nSMM 410 on the sub-
network 480, the future serving mobility manager. The nSMM 410 sends a
DHCPv6 Req 515 to the DHCPv6 430 requesting a new address to allocate as a
care-of address. The DHCPv6 430 transmits the care-of address to the nSMM
15 410 in a DHCPv6 Res 520.

 The nSMM 410 transmits a Hand-off and Context Transfer Response
(HCT Res) 525 allocating a care-of address to the oSMM 412. The oSMM 412
allocates HAn 426 to bi-cast the data destined to MN 464 to both the old and new
care-of address. To accomplish this, a BU 530 is transmitted from the oSMM 412
20 to HAn 426, which will respond with a BA 535 to oSMM 412. The oSMM 412
will then send a System Hand-off Response message (SHO Res) 540 to confirm
execution of the hand-off procedures and transmit the allocated care-of address to
MN 464.

 After the MN 464 receives SHO Res 540 from oSMM 412 and establishes
25 a Layer-2 connectivity with the nSMM 410 on new sub-network 480, it will send

5 BU 545 to HMM 440 to update the current binding on the home sub-network 482
with the new care-of address. The HMM 440 will update the binding to HAm
425 by sending a BU 550 to HAm 425, which in turn will transmit a BA 555 to
the HMM 440. The HMM 440 will transmit a BA 560 to the MN 440
acknowledging the BU 545. The HMM 440 will also update the binding on CN
10 474 with the care-of address by transmitting a BU 565 to the CN 474, and the CN
474 will acknowledge with a BA 570. If the MN 464 does not receive a SHO Res
540 from oSMM 412 because it has Layer-2 disconnection with the current
foreign sub-network 481, the MN 464 will initiate the Reactive Intra-Domain
Hand-off protocol.

15 Figure 7 shows MN 664 powering up on a foreign network 700. The MN
664 is connected to the foreign network 700 by communication link 659. The
foreign network 700 includes the FAAA 621, the DHCPv6 631, and the nSMM
610. The communication link 659 can be a wired or wireless connection.
Communication link 659 is connected to the nSMM 610. The nSMM 610 is
20 coupled to a buss line 653 by communication link 615. The foreign AAA server
(FAAA) 621 is coupled to the buss line 653 by communication link 652, and the
DHCPv6 server 631 is coupled to the buss line 653 by communication link 633.

The foreign network 700 is coupled to the Internet 670 by communication
link 673, which is coupled to buss line 653. The Internet 670 is coupled to the

5 home network 699 by communication link 671, which is connected to buss line 654.

The home network 699 includes the HAAA 620, the HMM 640, and the HAM 625. A home AAA (HAAA) server 620 is coupled to buss line 654 by communication link 656. A HMM 640 is connected to buss line 654 by
10 communication link 617, and HMM 640 is connected to HAM 625 by communication link 619.

When the MN 664 powers up on foreign network 700, Figure 8 shows the message flow under the new embodiment. This embodiment is referred to as an Inter-Domain Power Up Registration. The MN 664 sends a Reg Req 705 to the
15 nSMM 610 on the foreign sub-network 700 to obtain a co-located, globally routable address. The format of the IP header for Reg Req 705 is the same as shown in Fig. 1A. The nSMM 610 validates the identity of the MN 664 using coincidental information in the Reg Req 705. After validation, the nSMM 610 transmits a DHCPv6 Req 710 to the DHCPv6 server 631. The DHCPv6 server
20 631 allocates a co-located IP address to use as a care-of address and sends a DHCPv6 Res 715 back to the nSMM 610 with the new care-of address.

At this point, the nSMM 610 may generate and transmit an optional IP Offer message 720 to the MN 664 containing the care-of address for temporary use while registration is completed. The nSMM 610 will generate and transmit an
25 AAA Registration and Authentication Request message (AAA Reg Req) 725 to

5 the FAAA 621. The FAAA 621 receives the AAA Reg Req 725 and forwards an AAA Registration and Authentication Response message (AAA Reg Res) 730 to the HAAA 620 based on the network access identifier extension (NAI) contained in the AAA Reg Req 725.

When the HAAA 620 receives an AAA Reg Req 730, it authenticates the
10 identification and authorization of the MN 664. If the MN 664 authentication and authorization are affirmative, the HAAA 620 forwards the AAA Reg Req 735 to the HMM 640. The HMM 640 will process the AAA Reg Req 735. If the MN 664 lacks a home IP address, the MN 664 will have requested allocation of one. If requested, the HMM 640 will allocate a home IP address for the MN 664. If
15 the home network 699 is provisioned with multiple home agents for load distribution, the HMM 640 may designate HAn 625 to serve the MN 664. The HMM 640 will then construct an AAA Registration and Authentication Response message (AAA Reg Res) 740 with this information on the designated HAn 625 and the authentication data and transmit an AAA Reg Res 740 to the HAAA 620.

20 The HAAA 620 will transmit an AAA Reg Res message 745 to the FAAA 621, which will contain a care-of address for use by the MN 664 allocated by the DHCPv6 sever 631 and any home IP address allocated by the HMM 640 as well as affirmative confirmation of AAA. The FAAA 621 will transmit an AAA Reg Res 750 to nSMM 610, and the nSMM 610 will generate and transmit a Reg Res
25 755 to the MN 664 containing the allocated care-of address and any home IP

5 address. Once the MN 664 receives the Reg Res 755, it sends a BU 760 to the
HMM 640 or any assigned HAm 625. The HMM 640 or HAm 625 will then
respond with a BA 765, completing the registration.

Figure 9 depicts the situation where a MN 864 has moved and does a
hand-off from one foreign network 899 to a new foreign network 900. Figure 9
10 shows three networks 898, 899, and 900. The old foreign network 899 has an old
FAAA server (oFAAA) 845, an old SMM (oSMM) 810, and a foreign agent (FA)
830. The new foreign network 900 has a new FAAA server (nFAAA) 850, a
DHCPv6 server 860, and a new SMM (nSMM) 815. The home network 898 has
a home AAA server (HAAA) 840, a home mobility manager (HMM) 820, and a
15 home agent (HA) 825.

On the old foreign network 899, the FA 830 is connected to the oSMM
810 by communication link 831. The oSMM 810 is connected to a central buss
line 877 by communication link 811, and the oFAAA 845 is connected to the
central buss line 877 by communication link 812. Although a wireless connection
20 is shown linking MN 864 to nSMM 815, alternatively the link connecting MN
864 to nSMM 815 could be a wired connection.

On the new foreign network 900, the MN 864 is connected to transceiver
860 by wireless link 866. The transceiver 860 is connected to the nSMM 815 by
communication link 859, and the nSMM 815 is connected to central buss line 871
25 by communication link 817. The central buss line 871 is connected to nFAAA

5 850 by communication link 821 and to DHCPv6 server 860 by communication link 819. On the home network 898, the HAAA 840 is coupled to a central buss line 873 by communication link 841. The HMM 820 is connected to the central buss line 873 by communication link 823, and the HA 825 is connected to the HMM 820 by communication link 827.

10 The three networks, 898, 899, and 900 are also connected to the Internet 870. The old foreign network 899 is connected to the Internet 870 by communication link 881, which is coupled to the central buss line 877. The new foreign network 900 is connected to the Internet 870 by communication link 883, which is coupled to the central buss line 871. The home network 898 is
15 connected to the Internet 870 by communication link 882, which is coupled to central buss line 873. MN 864' is shown moving from a location connected to oSMM 810 to a new location connected to nSMM 815.

Figure 10 depicts the message flow for the embodiment where the MN 864 moves unexpectedly from one foreign network 899 to another foreign
20 network 900 and performs a hand-off. This embodiment is referred to as a Reactive Inter-Domain Hand-off. The MN 864 sends a Reg Req 905 to the nSMM 815 to obtain a co-located, globally routable address. The format of the IP header for the Reg Req 905 is the same as shown in Fig. 1A. The nSMM 815 validates the identity of the MN 864, and then transmits a DHCPv6 Req 910 to
25 the DHCPv6 server 860. The DHCPv6 server 860 allocates a new address to use

5 as a care-of address and sends a DHCPv6 Res 915 back to the nSMM 815. At
this point, an optional IP Offer message 920 containing the care-of address for
temporary use until the registration process is complete may be sent to the MN
864 by nSMM 815. The nSMM 815 sends an AAA System Hand-off and
Context Request message (AAA SHC Req) 925 to oSMM 810 to allocate an
10 agent, FA 830, in the old foreign network 899.

The oSMM 810 will allocate FA 830 to forward information packets to the
MN 860 by generating and transmitting a BU 930 to the FA 830. This will cause
the FA 830 to forward information packets from the old care-of address to the
new care-of address. This binding will last until registration is complete and then
15 expire. The FA 830 will respond with a BA 935 back to the oSMM 810
acknowledging the BU 930.

The oSMM 810 will verify the AAA SHC Req 925 by sending an AAA
System Hand-off and Context Response message (AAA SHC Res) 940 to the
nSMM 815. The nSMM 815 will verify the message and allocate a co-located
20 care-of address for the MN 864, which it will transmit to the MN 864. The
nSMM 815 will generate and transmit an AAA Registration and Authorization
Request message (AAA Reg Req) 945 to the nFAAA 850, which forwards the
message to the HAAA 840 based on the network access identifier (NAI)
extension in the MN 864 Reg Req 905.

5 When the HAAA 840 receives the AAA Reg Req 945, it authenticates the
identification and authorization of the MN 864. If the MN 864 authentication and
authorization are affirmative, the HAAA 840 forwards an AAA Reg Req 950 to
the HMM 820. The HMM 820 will process the AAA Reg Req 950. If the MN
864 lacks a home IP address, the MN 664 will have requested allocation of one.
10 If requested, the HMM 820 will allocate a home IP address for the MN 864. If
the home network 699 supports more than one HA 825 for load distribution and
balancing, the HMM 820 may designate a HA 825 to serve the MN 864.

 The HMM 820 will construct an AAA Registration and Authorization
Response (AAA Reg Res) 955 with this information on the designated HA 825
15 and the authentication data and transmit the message back through the HAAA 840
and nFAAA 850 to nSMM 815. The HAAA 840 will forward the AAA Reg Res
960 to nSMM 815. The nSMM 815 will generate and transmit a Reg Res 965 to
the MN 864 containing the allocated, co-located care-of address, any home
address for the MN 864, and confirmation of authorization and authentication.
20 After receiving the Reg Res 965, the MN 864 completes the registration by
sending a BU 970 to the HMM 820 or any assigned HA 825, which will
acknowledge with a BA 975.

 Figure 11 shows an embodiment where MN 1064 is aware of moving prior
to moving from old foreign network 999 to new foreign network 1000 and
25 requests a hand-off prior to moving. Figure 11 shows three networks 998, 999,

5 1000. The old foreign network 999 includes an oFAAA 1045, an oSMM 1010,
and a FA 1030. The new foreign network 1000 has an nFAAA 1050, a DHCPv6
server 1060, and an nSMM 1015. The home network 998 has a HAAA 1040, a
HMM 1020, and a HA 1025.

On the old foreign network 999, the FA 1030 is connected to the oSMM
10 1010 by communication link 1031. The oSMM 1010 is connected to a central
buss line 1077 by communication link 1011, and the oFAAA 1045 is connected to
the central line buss 1077 by communication link 1012. The MN 1064 is
connected to a transceiver 1060 by wireless link 1066, and the transceiver 1060 is
connected to the oSMM 1010 by communication link 1059. Although a wireless
15 link 1066 is shown, alternatively, MN 1064 could be connected to the oSMM
1010 by a wired communication link.

On the new foreign network 1000, the nSMM 1015 is connected to a
central line buss 1071 by communication link 1017. The DHCPv6 1060 is
connected to the central buss line by communication link 1019, and an nFAAA
20 1050 is connected to the central buss line 1071 by communication link 1021.

On the home network 998, the HAAA 1040 is coupled to a central buss
line 1073 by communication link 1041. The HMM 1020 is connected to the
central buss line 1073 by communication link 1023, and the HA 1025 is
connected to the HMM 1020 by communication link 1027.

5 The three networks 998, 999, and 1000 are also connected to the Internet
1070. The old foreign network 999 is connected to the Internet 1070 by
communication link 1081, which is coupled to the central buss line 1077. The
new foreign network 1000 is connected to the Internet 1070 by communication
link 1083, which is coupled to the central buss line 1071. The home network 998
10 is connected to the Internet 1070 by communication link 1082, which is coupled
to the central buss line 1073. The MN 1064' connected to nSMM 1015 is the
location the MN 1064 is moving to.

Figure 12 shows the message flow for the embodiment where the MN
1064 lacks Layer-2 connectivity to a new foreign network 1000 it is aware it is
15 moving to and performs a hand-off to move to the new foreign network 1000.
This embodiment is referred to as a Proactive Inter-Domain Hand-off. The MN
1064 sends a System Hand-off Request message (SHO Req) 1105 to the oSMM
1010 when it detects that it is moving to new foreign network 1000. The format
of the IP header for SHO Req 1105 is the same as shown in Fig. 1A. The oSMM
20 1010 sends an AAA Hand-off and Context Transfer Request message (AAA HCT
Req) 1110 to the future nSMM 1015 via the oFAAA 1045 on the old foreign
network 999 and nFAAA 1050. The nSMM 1015 transmits a DHCPv6 Req 1115
to the DHCPv6 1060 to obtain a new address to use as a care-of address. The
DHCPv6 1060 allocates an IP address and sends a DHCPv6 Res 1120 back to the
25 nSMM 1015 with a care-of address. The nSMM 1015 then generates and

5 transmits an AAA Hand-off and Context Transfer Response message (AAA HCT Res) 1125 to the oSMM 1010 again via the nFAAA 1050 and oFAAA 1045 with the care-of address.

The oSMM 1010 allocates a FA 1030 to bi-cast data destined for the MN 1064 to both the old and new care-of address by transmitting a BU 1130, and the
10 FA 1030 will transmit a BA 1135 back to the oSMM 1010. The oSMM 1010 will then send a System Hand-off Response message (SHO Res) 1140 back to the MN 1064 to confirm executing the hand-off and transmitting the co-located care-of address to the MN 1064.

When the MN 1064 receives the SHO Res 1140 from the oSMM 1010 and
15 establishes Layer 2 connectivity to the new foreign network 1000, it will transmit a Reg Req 1145 to the nSMM 1015. The nSMM 1015 will then construct and transmit an AAA Registration Request message (AAA Reg Req) 1150 to the HAAA 1040 via nFAAA 1050. The HAAA 1040 will authenticate the MN 1064. If the MN 1064 authentication and authorization is affirmative, the request is
20 forwarded to the HMM 1020 for further processing by an AAA Reg Req 1155.

The HMM 1020 updates the user state information, allocates HA 1025 to serve MN 1064, and constructs an AAA Registration Response message (AAA Reg Res) 1160 to transmit to the HAAA 1040 conveying the data. When the HAAA 1040 receives the Reg Res 1160, it in turn generates and transmits an
25 AAA Reg Res 1165 to the nSMM 1015 via nFAAA 1050. The nSMM 1015 then

5 sends a Reg Res 1170 to the MN 1064 conveying the information. Once the MN
1064 receives a Reg Res 1170, it proceeds to complete registration by sending a
BU 1175 containing the care-of address to the HA 1025, which acknowledges
with a BA 1180.

As a further alternative embodiment in each of these embodiments the
10 mobility managers (SMM 10, HMM 40, nSMM 210, oSMM 212, HMM 240,
nSMM 410, oSMM 412, HMM 440, nSMM 610, HMM 640, oSMM 810, nSMM
815, HMM 820, oSMM 1010, nSMM 1015, and HMM 1020) may maintain a
pool of addresses to allocate as care-of addresses to mobile nodes. If there is a
pool of addresses to allocate, then the DHCPv6 Request messages (110, 310, 615,
15 710, 910 and 1115) and the DHCPv6 Response message (115, 315, 620, 715, 915,
and 1120) are eliminated. In place of these messages (110, 115, 310, 315, 615,
620, 710, 715, 910, 915, 1115, and 1120) the SMM 10, nSMM 210, nSMM 410,
nSMM 610, nSMM 815, and nSMM 1015 will periodically request a new pool of
addresses from the DHCPv6 server to allocate as care-of addresses.

20 While the invention has been particularly shown and described with
respect to preferred embodiments, it will be readily understood that minor
changes in the details of the invention may be made without departing from the
spirit of the invention. Having described the invention, we claim: